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Preliminary Note on a Method of Photographing the Moon with Surrounding Stars. By H. H. Turner, D.Sc., F.R.S., Savilian Professor.

1. If the Moon and surrounding stars can be photographed simultaneously, we can measure the place of the Moon in the same way as that of a planet, comet, or other object, by reference to the surrounding stars; and such observations will be specially valuable near new Moon, when meridian observations are difficult or impossible. It was to obtain observations of the Moon in the first and last quarters that Airy set up the altazimuth at Greenwich in 1847; and unfortunately the instrument did not satisfactorily solve the problem. The present Astronomer Royal has recently set up a larger and steadier instrument with the same end in view, and already something is known of the success which is likely to attend the experiment. But even if early promise is fulfilled, there is ample room for an alternative photographic method.

2. It has for some time been in my mind to adapt for this purpose the method of observation suggested by Captain Hills, R.E., for obtaining terrestrial longitudes. (See *Mem. R.A.S.*, liii. p. 117.) With a fixed camera he takes snapshots of the Moon at times carefully recorded; and *at other times*, when the Moon has passed out of the field (or before it has entered it), a bright star or a planet is photographed on the same plate—several short trails being taken at recorded times. The method is applicable as it stands to the determination of the Moon's place, the disadvantages, however, being:

(*a*) Errors in recording the separate times of exposure enter directly into the inferred R.A. of the Moon.

(*b*) We can only use bright stars or planets, and must thus have rather a large field, or wait long intervals to secure them; perhaps both. The former condition means that the scale of the photograph will in general be small; the second introduces dangers of the camera being moved, or refraction changing considerably in the interval.

3. The second disadvantage can be considerably reduced by the device of a moving plate, moving at the same rate as the stars, and thus allowing faint stars to be impressed by accumulated exposure, which is not possible with trails. The position of the plate can be recorded by photographing on it a fixed point of light, the image of which is cut off automatically by the clock at regular intervals.

4. But a simpler expedient recently occurred to me as follows:—Point an ordinary photographic equatorial to the Moon and its surrounding stars and prepare in the usual way to take a photograph of the region, by an exposure of (say) one minute or of several minutes even, guiding on a star, so that stars of ninth

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or tenth magnitude at least would in the ordinary course (*i.e.* if the Moon were not there) be impressed. But cover up the Moon by an opaque screen, C D E F, which is a rectangle of sides, C D, something more than the Moon's diameter, and C E double C D. Let there be a narrow slit, A B, across the middle, and during the exposure let the screen be slowly drawn across the Moon's image in the direction X Y. Then successive portions of the Moon are exposed for short periods determined by the width of the slit and the rate of travel. By selecting these elements properly we can get good definition on the Moon. The image will, of course, be a distorted image—an ellipse instead of a circle—and in measuring different craters on the Moon allowance must be made for the difference in epoch of exposure. The star images are produced by the summation of a series of exposures, each of which has a corresponding portion of the Moon; and theoretically we should measure *every* portion of the Moon to get an accurate correspondence with the stars; but in practice it will probably be found that sufficient accuracy is obtained by measuring a few well-selected craters. There is in any case an obvious gain over any method which gives one short exposure to the whole Moon and a longer exposure to the stars, leaving us all the uncertainties involved in finding the relation between the two exposures.

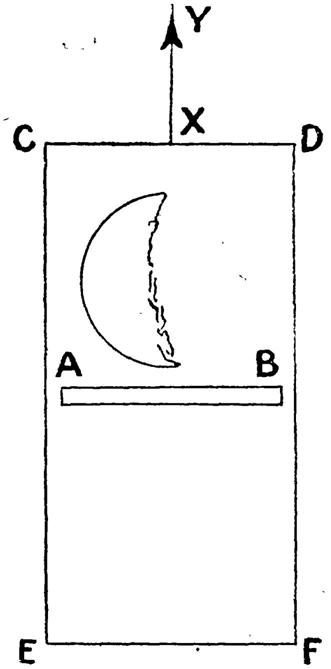

Fig. 1.

5. It will be seen that this method overcomes at once the two chief difficulties:

(*a*) The brightness of the Moon.
(*b*) Its rapid motion among the stars.

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6. Several trials of the method have been made at Oxford with very promising results. The first was on October 26 about 6 P.M., when the Moon was about six days old: R.A. $19^{\rm h}\ 0^{\rm m}$, decl. $-17^\circ\ 30'$; Z.D. about 70°. An exposure of three minutes was given. The screen was attached to a fixed object by a string, and thus the motion of the telescope automatically drew the screen across. On development the plate was, of course, found to be much fogged by the moonlight, but the following stars were easily recognised upon it.

	Zone.	No.	Mag.		Zone.	No.	Mag.
Schönfeld ...	−19°	5312	6·0	Schönfeld ...	−19°	5281	8·5
„ ...	−19	5273	6·1	„ ...	−19	5323	8·5
„ ...	−18	5206	6·5	„ ...	−19	5304	8·8
„ ...	−19	5275	7·0	„ ...	−19	5324	9·0
„ ...	−19	5317	7·4	„ ...	−18	5222	9·0
„ ...	−18	5219	7·8	„ ...	−18	5211	9·1

And there may be others also. Many stars are, of course, lost by the screen, and those in zone -17° were not looked for.

7. Other trials on October 28, October 30, and November 6 were made with shorter exposures as the brightness of the Moon increased, and ninth magnitude stars were not always shown, though there was no difficulty in getting eighth magnitude. These preliminary trials show that in the first and last quarters, which are the most important, we can get plenty of stars.

8. The screen may be trailed in any direction. The convenience of moving it in declination is that the whole length of path is approximately constant and equal to the Moon's diameter. But in some cases it might be more convenient to trail it in R.A. For instance, this method might be used in place of that of Captain Hills described in § 2, if a moving plate be provided. Point a *fixed* telescope to the region round the Moon, and let the plate move so as to follow the stars. Cover up the Moon with a *fixed* screen having a slit in it; the Moon's image will transit the slit along with the plate and give the desired result.

9. The method has the drawback common to all photographic methods, that it requires finer weather than eye observations. We can observe the Moon through cloud, but we can scarcely photograph faint stars. For this reason, if a successful attempt is to be made to get a good series of observations of the Moon near new Moon, photographs should be taken at more than one observatory.

10. We may hope by experiment to improve the details; but when such good results were obtained on the very first trial, it seems doubtful whether there is anything essential to be added. One small point may be noticed. To check the uniformity of motion of the slit, it is advisable to close the exposing shutter for a few seconds once or twice during the exposure, recording the

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times carefully. Also care should be taken to provide that some portion of the Moon shall be shining through the slit during the whole of the exposure. It is, of course, not necessary to photograph the whole visible Moon.

11. The present note is written with the object of attracting attention to the method, which, it is hoped, will be tried at other observatories, especially those in fine climates. The new apparatus required is practically negligible. A good series of photographs of the Moon of this kind, taken day by day from last quarter to first quarter in lunations extending over a year, say, would be of immense value. By combination of observatories in different parts of the world a very complete series might be secured.

12. Attention may also be drawn to the note by Mr. B. H. Wade in the present number, on observations of the Moon as a possible check on longitude observations.

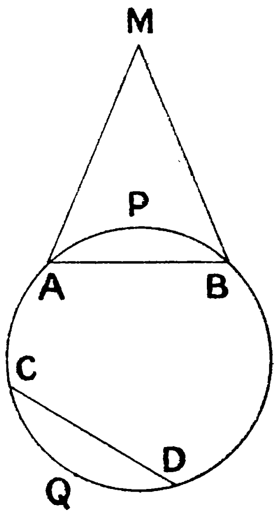

FIG. 2.

To state his point in rather different words : if we have two approximately equal arcs A B, C D on the Earth's surface, it is well known that we may test their equality in two ways.

(*a*) By direct (geodetic) measurement of the arcs A P B and C Q D.

(*b*) By astronomical observations of the angle between the verticals at A and B, using stars as an intermediary ; and similar observations of the angle between the verticals at C and D.

Mr. Wade points out that there is a third method, *independent* of these two, viz. :

(*c*) Observation of the angles subtended at the Moon by the chord A B and the chord C D.

13. These observations are comparatively rough owing to the great distance of the Moon ; but they may serve as a useful check, particularly if sufficient pains are spent on the lunar

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observations, *e.g.* by numerous repetitions. If photographs of the Moon among the stars were assiduously taken over long periods at numerous observatories, it does not seem impossible that we might obtain ultimately information as to the figure of the Earth comparable in value with that derived from telegraphic longitudes. For at present the latter are only made at rare intervals; and they are affected by some unknown, though small, sources of error, especially when submarine cables are employed. For instance, there is as yet no means of checking the fundamental assumption which enters into all telegraphic longitudes, that the time of transmission of an electric signal from A to B is the same as the time of return from B to A. The error of this assumption is no doubt a fraction of the whole time of transmission, but the latter may be as much as $0^s.3$ across the Atlantic, and there is room for an error of $0^s.05$ in the assumption of equal velocity to and fro. Good lunar observations systematically compared ought to be capable of easily checking such quantities as this.

Errors in the Moon's Tabular Longitude as affecting the comparison of the Greenwich Meridian Observations from 1750 with Theory. By P. H. Cowell.

(*Communicated by the Astronomer Royal.*)

I preface the account of my investigations with some extracts from the researches of various lunar theorists. I also exhibit a comparison between Airy's expression for the tabular longitude of the Moon and Hansen's. Had I realised when I made a certain analysis described in this paper that the errors of Airy's formula would produce a large systematic effect, as I endeavour to show in this paper that they do, my analysis would have taken a slightly different form. However, I now publish such results as I have obtained, and also the evidence on which I base the conclusion that the longitudes from 1750 to 1851 should be compared with a better formula than Airy's. I may also add that the bulk of the labour of this paper consisted in arranging the errors for analysis, and that this arrangement will enormously simplify the labour of correcting Airy's tabular places. The small fraction of the computations that represent the analysis after the arrangement was complete will in the near future be revised, but the provisional results are now published.

The arrangement which I refer to above as having formed the bulk of the labour is not described in this paper, nor are the details of the analysis. Complete information will be given with the corrected results.

The terms with coefficients over $0''.3$, of which it is necessary to take account in the longitude of the Moon due to causes other

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Erratum,

Referring to p. 22, paragraph 12. Mr. Wade's paper has been delayed in publication, and will appear in the next number of the *Monthly Notices.*